Surface Waves Response To Offshore Wind Farms Off The Coast Of New England

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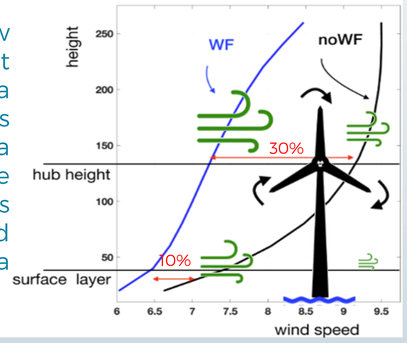
Introduction

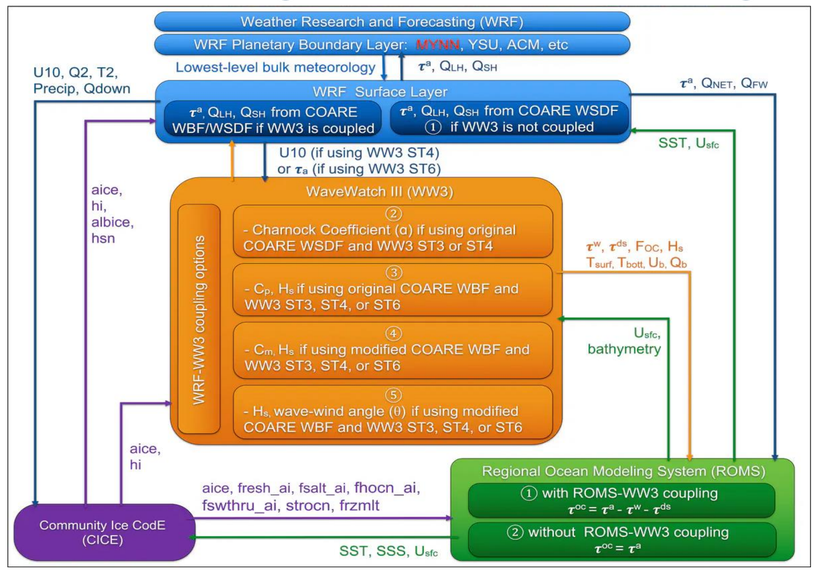
Offshore wind turbines extract kinetic energy from the atmosphere at wind farm scales, reducing wind speeds and producing downstream wind wakes of enhanced turbulence. The accelerated developments of large-scale offshore wind farm clusters are expected to modify regional wave climates.

This study investigates the surface wave response to large-scale offshore wind farms in the northeastern U.S continental shelf. Our analysis focuses on the boreal summer, a season characterized by relatively stable atmospheric conditions and pronounced wind wake effects.

Understanding how offshore wind farms affect ocean surface waves via the wind wake effect is important for the air-sea interaction perspective since surface waves modulate surface drag and support a bulk of air-sea momentum exchanges.



SCOAR Regional Coupled Modeling



Experiments	Wind Farms (WF)	Wave-Atmosphere Coupling
WF	Yes	Yes
NOWF	No	Yes
WF_NWC	Yes	No

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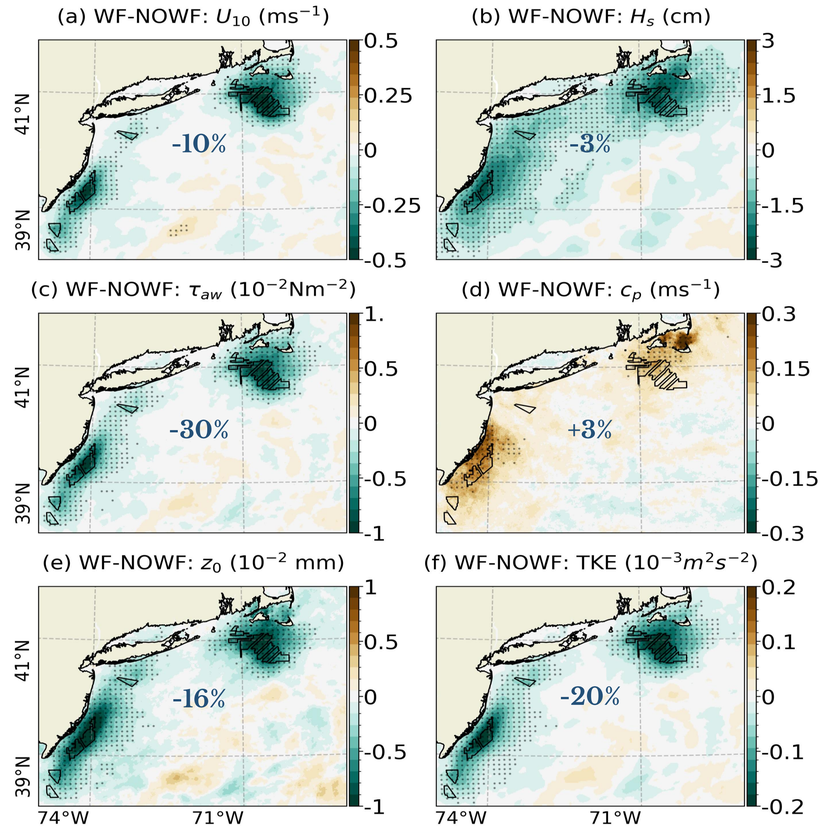
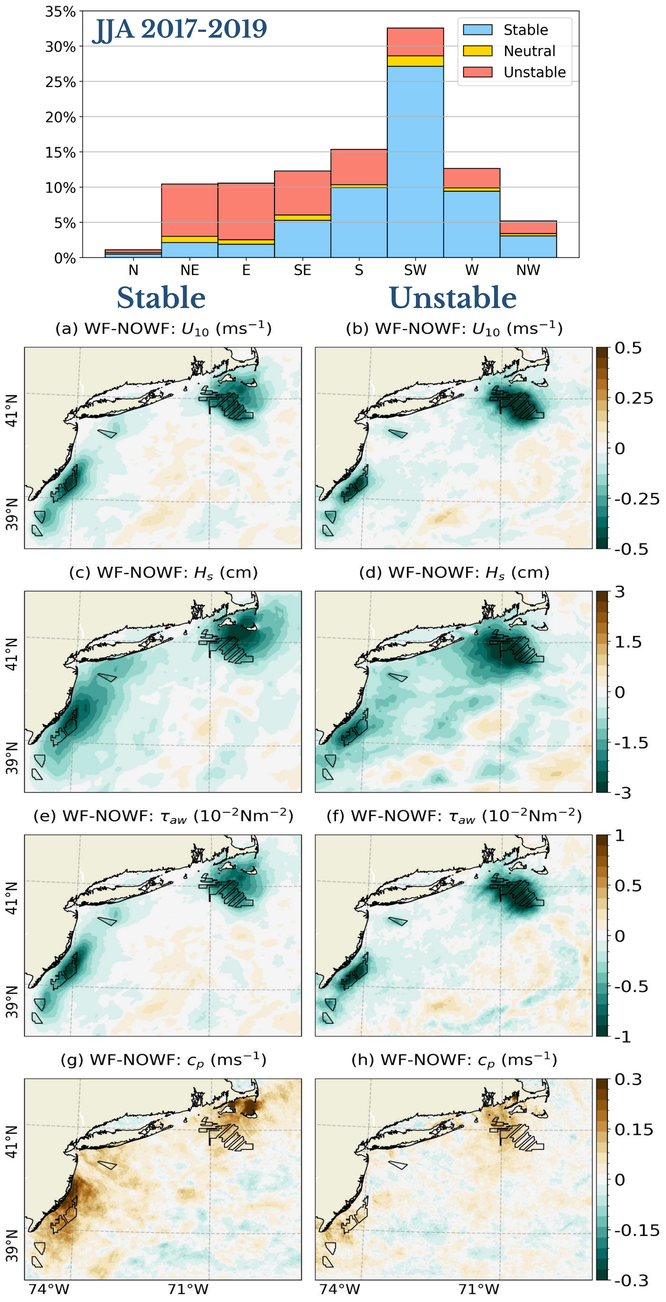
Wave-based roughness length: $z_0 = H_s 0.09(\frac{u_*}{c_p})^2 + 0.11\frac{\nu}{u_*}$

1418 turbines are represented using the "Fitch" parameterization in WRF.

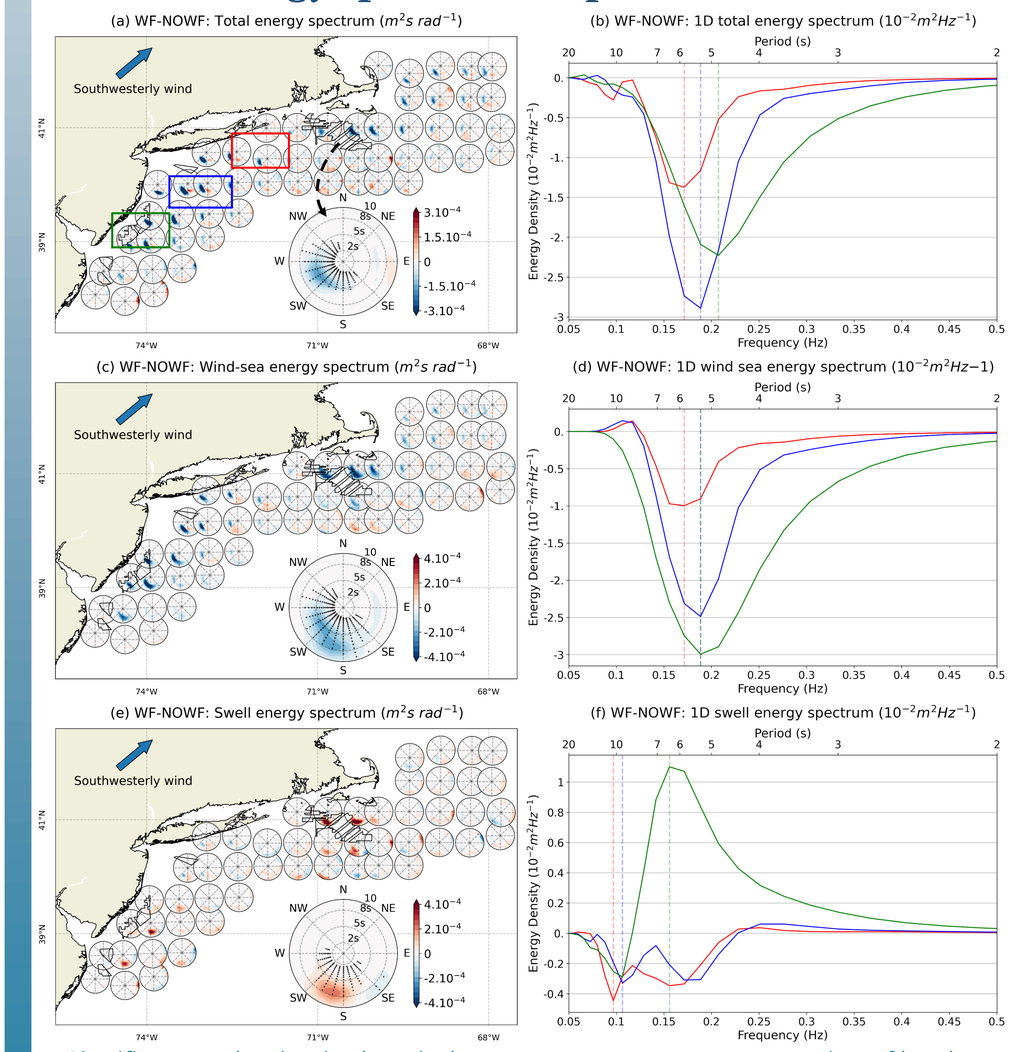
1-Mean sea state responses JJA 2017-2019



2-Sensitivity to atmospheric stability



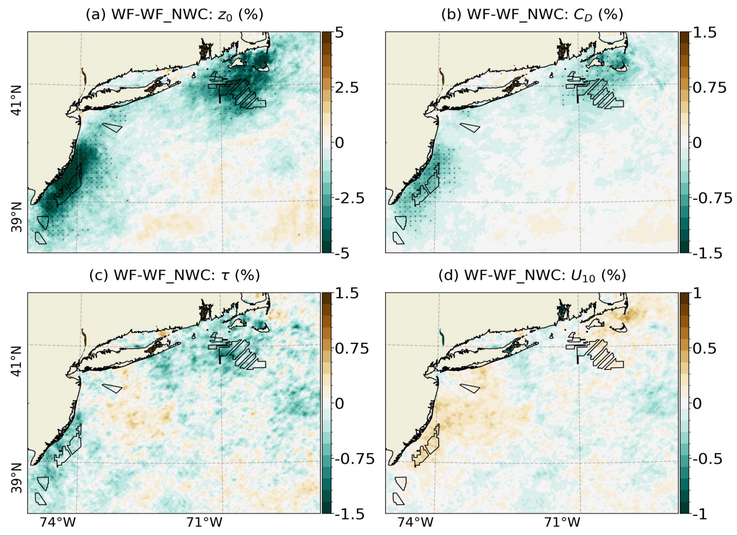
3-Wave energy spectrum responses



- Significant reduction in the wind-sea energy suggests a suppression of local wind-wave growth near the wind farms.
- Weaker winds favor the dominance of swell waves. The fully developed waves generated upstream of the wind farms outpace the local wind when entering the lease areas, where surface winds are reduced by wind turbines.

4-Isolating wave impact on surface drag

- The wind farms-induced sea state changes reduce the parameterized z0 by ~5%.
- The resulting changes in drag coefficient and momentum flux are small and statistically insignificant.



Key Takeaways

- Surface wind speed is reduced up to 10% in the wind farm wake while wave height and wave-supported stress are decreased by 5% and 30%.
- The lower wind-sea energy density suggests reduced wave growth in the vicinity of the wind farms.
- Weaker winds favor the presence of longer-period waves, altering the local wave regime and further reducing the ocean surface roughness length.
- The primary driver of reduced stress is the wake-induced decrease in wind speed, while sea state changes play a secondary role.